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PAPERS

RELATING TO

THE RIVER TYNE,

ORDERED TO BE PRINTED

BY THE

RIVER COMMITTEE,

MARCH, 1836.

31

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MARCH, 1836.

NEWCASTLE:
PRINTED BY T. AND J. HODGSON, UNION-STREET.
1836.

30·II [illegible]

MR. RENNIE'S REPORT.

London, June 17, 1816.

There is, perhaps, no river in Great Britain on which it is more difficult to give a satisfactory opinion, as to the best mode of improving its navigation, than the river Tyne. In this river not only is great depth wanted, but likewise great width, to accommodate the immense number of ships which resort to it; these two qualities, however, are incompatible with each other. If the width of the river were to be contracted by a solid embankment, its depth would be increased, but then the space for the accommodation of shipping would be lessened; and, as a less quantity of tide water would thereby be admitted, it would have less effect in keeping down the bar; but this is not all, for when ships are working into the harbour with an adverse wind and flowing tide, there would be less current to carry them across the bar, so that in gaining depth of water in the channel of the river, care must be taken that the depth on the bar be not diminished. A solid embankment on the side of the river must, therefore, be avoided, or at least limited to a certain extent, and other means devised to effect the object; but to both there is a limitation, and, therefore, it becomes a nice point to settle with precision what depth can be obtained and maintained in the river Tyne, between its mouth and Newcastle Bridge, without contracting it to a degree that may prove materially injurious to the navigation.

From the very correct survey of the river Tyne, within the limits I have specified, and of its mouth, made by Mr. Giles in the year 1813, and also the soundings and sections taken by him, it appears that on the 30th day of May, 1813, being the second day after new moon, the rise of tide, from low water to high water at Shields, was 14 feet 11 inches; at Hebburn Quay, the same day, it was 12 feet 5 inches; at Newcastle, 11 feet 8 inches. The second day, after the first quarter, being the 7th of June, it rose 9 feet at North Shields, 8 feet 2 inches at Hebburn Quay, and 7 feet 7 inches at Newcastle. The second day after full moon, being the 16th of June, it rose 12 feet 7 inches at North Shields, 10 feet 8 inches at Hebburn Quay, and 10 feet 2 inches at Newcastle Quay. The second day after the last quarter of the moon, being the 23d of June, it flowed 11 feet 3 inches at North Shields, 10 feet at Hebburn Quay, and 8 feet 8 inches at Newcastle.

When the first and second observations were made, the wind was easterly, and blew fresh: when the observations after the full moon were made, it blew a strong northerly wind; but when the last observations were made, it was nearly a calm.

Many other tides were observed, as will appear by the sections or tables which accompany this report; from the inspection of which, it will appear that many of them differ considerably from those I have described. Taking, for example, the second day after new moon on the 30th of June, when the weather was moderate, the rise was 15 feet 2 inches at North Shields, 12 feet 2 inches at Hebburn, and 11 feet 3 inches at Newcastle: the neap, on the 7th of July, at North Shields, rose 8 feet 7 inches, at Hebburn Quay 8 feet 2 inches, and at Newcastle 7 feet 3 inches.

From the first set of observations I have stated, namely, the 31st of May, it appears that the rise at North Shields was 2 feet 6 inches more than at Hebburn, and 3 feet 3 inches more than at Newcastle; from the second observations, on the 7th of June, it appears that the rise was 11 inches more at North Shields than at Hebburn, and 1 foot 8 inches more than at Newcastle: from the third observations on the

16th of June, the rise at North Shields was 1 foot 11 inches more than at Hebburn Quay, and 2 feet 5 inches more than at Newcastle; and on the 23d of June, the rise at North Shields was 1 foot 3 inches more than at Hebburn Quay, and 2 feet 7 inches more than at Newcastle. Thus, the difference on these four respective tides at North Shields and Newcastle, was 3 feet 3 inches, 1 foot, 5 inches, 2 feet 5 inches, and 2 feet 7 inches. But the tide of the 30th of June, when the weather was calm, the difference was 3 feet 11 inches; the quantity of tide water thrown into the Tyne at each tide therefore varies exceedingly. This variation depends not only on the state of the tides themselves, but on the winds and on the quantity of fresh water which is in the Tyne itself; this renders it exceedingly difficult to draw any correct inference from calculations founded on data so very variable. It appears, from the observations made on the tides by Mr. Giles, for about four months, that the average rise of springs at North Shields was about 14 feet; at Hebburn, about 11 feet 10 inches; and at Newcastle, about 11 feet 7 inches; thus making a difference of rise, between North Shields and Hebburn Quay, of about 2 feet 5 inches, and of Newcastle 2 feet 8 inches. The average neap tides, for about the same period, flowed at North Shields 8 feet 10½ inches, at Hebburn Quay 7 feet 9½ inches, and at Newcastle Quay 7 feet 2½ inches; thus making a difference of rise, between North Shields and Hebburn Quay, of about 1 foot 1 inch, and of Newcastle of about 1 foot 8 inches. The tide observed on the 31st of May, though not an average spring tide, as it rose 14 feet 11 inches, is that which was taken as a data for all the soundings marked on the plans. This was done to save time; for had the soundings been delayed until the average spring tides had been ascertained, a principal part of the summer would have been lost. From the soundings, it appears that the whole quantity of water in the Tyne, between Shields Narrows and Newcastle Bridge, at the low water of the 31st of May, 1813, was about 214,262,000 cubic feet, and that at high water on the same day it was about

940,883,000, thus leaving 726,621,000 cubic feet for the quantity of tide water thrown into the above district. The velocity of the current of the flowing tide in springs, above Shields Narrows, is about 3 knots per hour at half flood; and about half ebb, the current is about 3¾ knots per hour. The width of the river is, however, so very various, that the rate of the current varies in almost every part of it, and is generally the greatest when Jarrow Slake is just covered, which is a little before half flood. Vessels entering the harbour at this time, frequently derive advantage from this great expanse; for if they enter with an adverse wind, the increase of current helps them over the bar, when they otherwise would not be able to enter the harbour at all. This slake is of great extent, covering upwards of 350 acres, and when the water is covering it, there is an increase in the velocity of the current of nearly one quarter of a mile per hour, an increase of material advantage to the shipping; and, indeed it forms a considerable portion of the area of the river between Shields Narrows and Newcastle Bridge; the whole of which, including this slake, is about 1694 acres at high water. Although a great extent of space to receive tide water is essential to the preservation of a good outfall, it must be observed, that the most advantageous space for the reception of this tide water is not the surface exclusively, which is in a considerable degree the case with the Tyne, where there are large sand banks, which are not covered with water until nearly half flood, after which the water has not so great an effect in scouring the bottom as at an earlier period of the flow, the like takes place in the ebb. In the Tyne, the sand banks are so numerous and high, that the flood is far advanced before they are covered with water, and, therefore, the current of the tide is sluggish; and, besides, the numerous eddies in the river greatly obstruct the flow. In like manner one-half the ebb is fallen off before the sand banks are dry, and by the time when it should be the greatest, its scouring force is in a great measure gone by, there being little water left in the river. Were these sand banks removed, and the tide had free ingress, it would flow with more rapidity in the first quarter of the flood; and in like manner it would return with more rapidity in the last quarter of the ebb, so that in both cases it would scour with more force, and make and maintain a greater depth of water. The time for which vessels could navigate the river would likewise be prolonged, and they would sooner get to their berths when inward bound; and in like manner would proceed down the river and get to sea before so much of the ebb was spent. To effect this essential improvement, I propose that the river shall be contracted in its wide places into a narrower channel, and in places where the width is already too small, it shall be enlarged; in doing these the curves must be made as uniform as the nature of the shores will admit, and that wherever there are any abrupt projecting points, which materially obstruct the current, that these points shall be cut off. The lines of contraction laid down by me are not, however, regular, they are always wider where the turns are; and, in general, the river has been laid out of a greater width where the greatest number of vessels generally lie in order that proper room may be afforded for others to pass and repass them. And as vessels, which lie in the river to take on board cargoes, not only occupy considerable space, but also occasion eddies, there is more space required for the tide water to pass them, than in places where vessels do not generally lie. It is possible, however, that experience may prove that these spaces should be still further contracted. The mode of contracting the river, where required, I propose to be the same as that practised in the river Clyde, which, with the addition to the plan suggested by me about eight or ten years ago, has proved so very successful, namely, by building jetties from each shore, and moving the sand and gravel out of the intended channel, by means of dredges, and depositing it in the spaces between the jetties, and when the channel was brought near to the depth it was expected the water would maintain, these jetties have been joined by walls of rubble stone, whereby the channel has been preserved of a regular depth. Without these junction walls this could not have been done, as the water would have spread between the points of the jetties, and thrown up sand banks which would thus have rendered the channel full of shoals. By the line of jetties laid down by me, the surface of the channel, supposing the tide to be confined within these points, will be reduced to about 896 acres, namely, 448 acres less than it now is at high water. Now the question is, how shall this deficiency of tide water, occasioned by the contraction, be supplied? Towards the supply of this deficiency there are several sand banks in the channel of the river, which are now dry at three quarters ebb, and there are others which are nearly dry at half ebb; of the former, are those at Jarrow Sands, amounting to about 21 acres, and of the latter, are Cock's Crow Sand, and several others, amounting to about 52 acres, making together about 73 acres, which will be reduced to a depth considerably under low water. In addition to this, I have to remark, that the river throughout, I mean the contracted channel, will be very much deepened, and consequently the low water will be depressed in its surface; and as the flood tide will be much less obstructed, it will flow further up the Tyne, and rise higher than it now does. And as it will receive the tide water in the first quarter of flood, and will retain this water until the last quarter of ebb, it will produce a much greater effect in scouring the bar in proportion to its quantity than it now does; and in addition to all these, it is proposed that the height of the jetties shall little exceed the height of half flood, so that a principal part of the space embanked will still remain as a receptacle for tide water. According to this plan, therefore, the scouring effect of the tide will be materially increased, and consequently the depth of water over the bar will be increased to the depth, I apprehend, of at least two feet.

The narrowing the river by means of jetties, is the most economical mode I can devise, and best suited to the circumstances of the case, for that part of the river which lies between Shields and Newcastle, but for the whole length of Shields, and most of Newcastle, I am of opinion the contraction should be made by regular wharf walls of masonry; and as the space gained will prove highly beneficial to the proprietors of property bordering on the river, I cannot for a moment doubt that they will be ready to make an allowance for the ground gained, if not to undertake the work at their own expense.

In some parts of the river the channel will require to be widened, such as at Whitehill Point, at Bill Point, at Hall & Co.'s lead smelting works, at St. Anthony's village, at Felling Shore copperas works, at Cinder Kilns, at Friar's ballast hills, and opposite the Northumberland glass houses, at the head of the Glass House Reach. By the cutting of these projections, the tide water will meet with much less interruption in its flow, and the freshes of the river will meet with less interruption in going off, and spread more regularly over the channel, so as to scour away the sand banks which now lie irregularly in the river, and thereby make and maintain a more uniform depth of water.

I have laid down the line of the channel which I would recommend to be adopted, and also the situation of the jetties which appear to me to be the best; but it is by no means unlikely that in the course of executing the work it may be found convenient to alter the places of several of the jetties to render them more suitable to the coal staiths on the sides of the river, several of which will require to be altered, and this will be attended with considerable expense; for I am of opinion, that if inlets or mud docks were to be made at these staiths, they would, in a short time, be sanded up, and thereby rendered useless, and wet docks at the respective staiths would be too expensive; so that under all the circumstances of the case it appears to me it will be better to lengthen or shorten the staiths, to render them suitable to the new intended channel of the river, than to adopt any other mode.

In regard to Jarrow Slake, I propose that it shall be left open as it now is; but to prevent this sand from being carried into the channel, it will be necessary to make a kind of flat facing of rubble stone, to admit of the tide passing over it and to prevent the sand from running into the channel upon the tide's ebbing from its surface, and indeed to preserve the channel along its edge, without which it could not be kept in its place.

Having now given my opinion on the best mode, as it appears to me, of improving the navigation of the river Tyne, between Shields Narrows and Newcastle Bridge, I shall next consider the best means of improving the entrance; but before I lay down my plan for this purpose, it will be necessary to state how the tides act on the mouth of the harbour.

The current in the offing begins to run to the northward about three hours after high water, and continues to do so until about three hours after low water, thus making a northern current about five hours; it then sets to the south, and continues in that direction until about three hours after high water, making a current to the south of about seven hours. But in-shore the change of current is different, for it makes to the south about a quarter of an hour after low water, and it begins to move towards the mouth of the harbour about 35 or 40 minutes after low water, and continues to run upwards for about five hours, and ebbs about seven hours; but if there is a strong fresh in the river, it is frequently half an hour later, and then it does not run upwards more than four hours.

In the making tide, when the current runs to the south, it sweeps round the head at Tynemouth Castle; and as the point of the Herd Sand is covered with water early in the flood, a cross current is formed at the Narrows, which throws a part of the tide over to the Low Lights Shore, while another part continues its direction upwards; by this cross current, the bank, called the Middle Ground, is formed. There is another sand bank, called the In-Sand, which unites with the tail of the Middle Ground, and this sand renders the access to the harbour difficult, it not being an easy matter for a ship moving with so rapid a current as there is in the Narrows to avoid it. If these two banks were removed, the access to the harbour would be much more easy and safe, for in this case vessels would run boldly for the harbour, which they cannot do at present: but an evil would arise out of this of considerable extent, namely, a heavy swell run into the harbour in strong easterly gales, as the waves would then have nothing to check them, and this would be attended with some danger to the shipping within. The total removal, therefore, of the Middle Ground and In-Sand is not what is wanted; but a partial one, so as to render the access easy, without admitting too much swell into the harbour. Nothing can exemplify this more strongly than the case of Aberdeen harbour, which, in the year 1769, was in a great measure similar to the harbour of Shields. There was a projecting rock, called Girdleness, on the south, and a long flat sandy shore on the north, from which a point projected and formed a narrow mouth; there was a middle ground, and what may be called an in-sand: the entrance was shallow, and ships lay in safety within the harbour, but the access was difficult. Mr. Smeaton's opinion was taken in the year 1770, on the best mode of improving this harbour, and he recommended a pier to be built on the north side, to prevent the seas from running into the mouth of it, where they not only occasioned great agitation, but also brought in large quantities of gravel and sand. This pier was found to answer the purpose of deepening the entrance, but it also removed the sand point, or ness, which formerly checked the in-run of the seas, and by this removal such a swell got into the harbour in easterly gales, as to occasion great damage to the shipping. Mr. Smeaton was therefore consulted again in the year 1788, when he advised that a jetty should be constructed where the old sand Ness Point formerly lay, to turn the waves into a different channel: this was done, and it effectually answered the purpose. Such an example ought not to be lost sight of, as it proves that a similar measure, with certain modifications, may be resorted to with safety in this case; and should it even turn out that the Middle Ground and In-Sand shall be scoured away, and the sea in easterly winds run with violence into the harbour, this can be prevented by a jetty properly constructed, so that no fears need be entertained of the ultimate success of the measure.

The situation and extent of a southern pier is, however, a matter of serious consideration. It should not be placed too near to the channel, as in this case it will not afford sufficient room for the free entrance of the tide, nor should it be placed too far from it, lest the cross current should not be sufficiently checked. I have placed it in the situation which appears to me the best; but should you determine to carry the measure into execution, it can be then set out with all due attention to the circumstances of the case. I have not laid down any plan for dry or wet docks, which may conveniently be constructed on the sides of the Tyne; but if you should adopt the plan I have recommended, these may be done at a future period.

With respect to the expence, it is no easy matter to be correct in a work of this nature and extent: I have, however, endeavoured to make out an estimate as near as I can, amounting to £519,320. This estimate is made on the supposition that the whole work shall be done out of the fund which may be raised for the works; but as I have before given it as my opinion that the stone walls, or wharfing, in South and North Shields, should be done in part, if not wholly, at the expense of the respective proprietors opposite whose property the new wharf walls are to be made (the earth or sand, to fill the spaces between the wharf walls and the land, should be provided at the expense of the harbour and navigation fund, because the removal of the sand is necessary to give depth of water in the river); this would occasion a saving of upwards of £80,000., and would reduce the estimate to £439,320. The works I have proposed are, in many cases, of a nature that do not require to be immediately carried into execution, and, indeed, it would be injudicious to do them so if even they could.

Where the channel of the river is to be materially changed, it should be done gradually; for if it were done otherwise, the sudden effect produced would greatly impede the navigation. The new proposed wharf walls in Shields may also stand over for some time to come, unless the proprietors of the property on the borders of the harbour think it advisable to commence upon them at an early period, which it would be their interest to do. The works that strike me as most material to be done first, are those which tend to direct the river in a straight, or, at least, an uniform, course, where it is most interrupted by sand banks. The effect of such works will be sooner felt than in other places where the channel is not so bad; and the pier on the Herd Sand is a material object. On this subject, however, I shall be more particular, should my plan be determined on to be carried into execution.

I am,
WORSHIPFUL SIR, and GENTLEMEN,
Your most humble servant,
JOHN RENNIE.

To the Worshipful the Mayor, Aldermen, and
Burgesses of Newcastle upon Tyne.

Estimate of the probable expence of the works proposed for the improvement of the navigation of the river Tyne and Shields Harbour.

	£.
To a pier on the Herd Sand,[*]	218,011
To a new wall from Half Moon Stairs to Bottle House Landing, including filling the space within,..	115,762
To a new wall from Walton's Salt Works to the south end of the High Docks, including the filling of the space within, ...	12,430
To a low rubble stone causeway across the entrance to Jarrow Slake for the water to pass and repass freely over it,............................	5,106
To building twenty one low jetties between Jarrow Slake and Hall & Co.'s Lead Works, and dredging sand from the channel of river,...	13,407
To cutting off a projection at Hall & Co.'s Lead Works, ...	3,300
To building eight small jetties between Hall & Co.'s Lead Works and Messrs. Brandling's Coal Staith, ...	684
To cutting off projection at ditto and at Goose Quay,......................	12,622
To the building of five jetties between Goose Quay and Ballast Hills,	537
To cutting off projections at Ballast Hills, and at a place above, ...	7,512
To the building five small jetties, ...	390
Carried forward,.........	£389,761

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[*] Mr. Giles, civil engineer, under date of the 17th of February, 1836, estimates the expense of this pier at £50,000.

Brought forward,	£389,761
To a new quay wall from the Low Lights Shore, in North Shields, to the Steam Mill, including the filling the space within,	34,110
To building four substantial jetties along the Droitwich Sand to near Whitehill Point,	2,316
To cutting away Whitehill Point and sands at ditto,	6,702
To the building of thirty one jetties between Whitehill Point and Bill Point, and dredging the sand from such projections as required,	18,500
To cutting off the projection at Bill Point,	16,630
To building six jetties between Bill Point and St. Anthony's Village,	1,068
To cutting off projecting land at St. Anthony's Village and Cinder Kilns,	23,683
To ditto at St. Peter's Quay,	920
To building six jetties at Newcastle Quay,	630
To altering coal staiths and other landing or shipping places, these articles I only guess at, but say,	25,000
Total,	£519,320

MR. RICHARDSON'S REPORT.

TO THE JOINT COMMITTEE OF THE COMMON COUNCIL AND THE CHAMBER OF COMMERCE OF NEWCASTLE UPON TYNE.

Newcastle on Tyne, 7th Month, 13th, 1834.

Gentlemen,

Agreeable to your request communicated to me by your Secretary, in a copy of your resolution of the "21st of May, 1834," I have bestowed great attention on the subject of improving the navigation of the river Tyne, and beg leave, respectfully, to report to you my opinions on the subject:—First, as to the possibility of improving the navigation from Wincombe-lee to Hay-hole; and, secondly, as regards the whole river from Newcastle to Shields.

After mature consideration, it appears to me, that by adopting certain measures, the depth of water may be increased, and the sand-banks and other obstructions removed to a considerable extent, at a comparatively slight expenditure.

Before proceeding to state to you the remedial plans by which I propose to achieve this important and very desirable object, you will, perhaps, allow me to observe, that a general survey or view of the river suggests the natural causes which have produced the present obstructions and the remedies to be applied to remove them.

The present appearance of the river clearly indicates that it has been increasing in superficial area for many years by the washing and falling down of the banks on both sides. As the surface was thus enlarged, the depth of water has been necessarily diminished by lessening the force of the tidal current, and thereby causing permanent depositions of sand and other materials in the bed of the river. I am confirmed in this view of the subject by the concurrent testimony of several respectable and intelligent gentlemen, who have been intimately acquainted with the river for many years, and also by that of the pilots and watermen with whom I have conversed on the subject.

Presuming, therefore, that I am correct as to the cause of the obstructions which now exist in the bed of the river, I feel little or no difficulty in recommending to you the partial adoption of the plan proposed by Mr. Rennie in 1816, for narrowing the river by the judicious erection of quay-walls. I say the *partial* adoption of Mr. Rennie's plan, because I do not conceive, that, at present, it would be either prudent or needful to incur the great expenditure, which, carrying all his plans into execution, would cause. And, although I generally approve of his plan, there are parts of it, the benefits accruing from which, would, in my opinion, be extremely problematical—as, for instance, his mode of building the quay-walls, and his erection of a pier at South Shields.

It does not appear to me needful to enter more minutely into the reasons which have induced me to recommend to you the contraction of the river after the very full report of Mr. Rennie, but I may, perhaps, be allowed to state why I differ from him in the plan he recommends to be followed in the building of the walls.

He proposes to effect this object by the erection of jetties connected by dwarf walls to the height of half flood only, on the supposition, that otherwise the admission of tidal waters would be impeded if not lessened.

The obvious disadvantage of this plan is, that the land inclosed would still remain unavailable for building or other purposes, whereas if the walls were built above flood height, the proprietors of the adjoining properties would, I have no doubt, in most instances, if not in all, be willing to build the walls at their own cost, were they permitted to have the land or quayage thus made.

By the calculation which I have made from measurements, taken from Rennie's plan, it appears that the quantity of land hereafter proposed to be enclosed, will be fully compensated for in the sectional area by the removal of the land and other existing obstructions. I, therefore, think Mr. Rennie has over-rated the probable increased quantity and velocity of the tides upon which he speculated, when he proposed building the jetties and walls only half flood high, and cannot see sufficient reasons for expending such large sums without the advantages in return which building the walls flood high would give.

The walls ought to be built on one general plan, from which no deviation ought to be allowed, and the section of the wall to be vertically sloped on the face either in a curved or straight line—the thickness of the wall ought to vary according to its situation and height, and every care taken that the foundation be well and securely laid, the space between the wall and the back ground ought to be filled up with either the sand dredged out of the river or the materials excavated in making the improvements herein recommended. Where quays or walls now exist, and which are not in accordance with this plan, either by their irregular lines, projections, or indentations, they ought to be removed and rebuilt in a proper manner, so that they may not act as some now do as quoins and mud-bays to the interruption of the current.

In a few situations it may be prudent to erect jetties, but as the wall will be above flood height the general adoption of them will be unnecessary.

I do not see that I can improve upon the line of walling laid down by Mr. Rennie, nor do I think it very material at what place it is first begun, so long as it is built continuously, that is without much time intervening between the erection of one part of a wall and that of another part, especially where the river is considerably contracted.

Presuming that the proprietors of the adjoining properties will be at the expense of the walling in front of their respective premises, I have not estimated it, as the cost of it will depend on its situation and height, but it may, I think, be built for twelve shillings per superficial square yard, as an average price for the whole distance. Dredging in the mode I propose, would cost five-pence per cubic yard; the quantity required to be moved in this way cannot be estimated in as much as we must not only anticipate a moving of the sands, but also an increasing diminution of them by the gradually acquired additional force of the current.

Although thus contracting the river would, undoubtedly, increase very considerably the scouring effect of the tides, yet this would be insufficient to remove in any short period the immense deposits now existing, and recourse must therefore simultaneously be had to artificial means until the channel was considerably cleared. This would, I think, be best effected by employing a steam dredging machine, at so much per cubic yard, for the quantity, &c. dredged and deposited in such places as might be, from time to time, pointed out. This could, I think, be done at the price named, as the places of deposit would be contiguous and easily accessible, especially if the dredging machine were to empty its work into keels fitted up with boxes with trap-bottoms, and a crane sufficiently powerful to lift the boxes out of the keel on to or over the wall where the sand was required to back the walls or fill up the spaces between the wall and the original back ground.

In the works I have suggested as likely to be benficial to the navigation of the river from Wincombe-lee to Hay-hole, I have included the contraction of the stream for the whole distance, although it is a question for your consideration, how far it would be expedient to erect all the walls (especially those on the slake at Cock-crow sand and opposite to Jarrow sand on the north side of the river, which are 9,500 feet in length, and from 700 to 800 feet in the broadest points of contraction), without parties are willing to undertake them on the conditions already mentioned.

From the good that has resulted by building the quay at contraction), without parties are willling to undertake them on the conditions already mentioned.

From the good that has resulted by building the quay at Tyne Main, there can be little or no doubt, but that generally even a partial adoption of this plan will tend materially to the improvement of the river, although this improvement would certainly be greater and more complete if the whole was executed.

With these observations, I shall close my report on the river from Wincombe-lee to Hay-hole, and proceed to consider on more general grounds, what alterations can be made in other parts of the Tyne, so as to give increased facilities to its navigation and greater effect to the plan already proposed. It appears to me requisite, that the proposed improvements ought not to be limited to any particular locality, inasmuch as even supposing the remedies proposed to be adopted, the traffic on the river would still be exposed to inconvenience and loss so long as other obstructions to a good navigation continued to exist. I make these remarks with a reference more particularly to the projections at Friar's Goose and Bill Point, thna which there are no obstructions of this description that more urgently require removal. At Friar's Goose, the buildings which have been erected on the projecting land, are of such a description as to entail so great an expenditure on their removal so as to carry into effect Mr. Rennie's plan, that I have not ventured to anticipate that such a course would be pursued were I to recommend it. I have, therefore, confined myself to what I have considered practicable, and suggest the propriety of cutting off down to low water mark, the extreme projecting point, which is a quay, and upon which a crane is now fixed, and to substitute for it another quay, a little more to the west, by building a connecting wall at the outside of a triangular space in the river. Thirty-three feet, at the least, might thus be obtained from the extreme point, and the whole quay rendered less angular, at a cost which I have estimated at £1,078.

Bill Point is, however, of the greatest importance, both as regards the accidents and loss which have occurred in consequence of it, and of the expenses necessary on its removal.

The channel of the river below the point is extremely narrow, there being scarcely room for two ships to pass each other, and above it a like inconvenience and danger arise from ships lying in that situation, and the inability of the parties coming up the river to see the course they ought to take to avoid collision and consequent damage. I know of no particular obstruction more decidedly prejudicial to the commerce on the river than this one, and, therefore, most strongly, but respectfully, urge upon your consideration the expediency of its removal. I have taken the needful levels on the line proposed by Mr. Rennie, and I find, on a liberal calculation, it might be removed to the extent he proposes, and excavated to the depth of low water mark for £11,600.

If this sum should be deemed too large to be expended on this object, a more circumscribed line might be adopted, and the expense reduced accordingly.

It is true, that any measure having for its object the removal of this point, however limited in its extent, cannot but prove highly beneficial, yet, so convinced am I of the great importance of this subject, that I should feel dissatisfied with myself were I not earnestly, but very respectfully, to advocate its entire removal as laid down in Mr. Rennie's plan.

Whether this be effected at once, or one part now and another part after, the lapse of time, becomes a question of comparative expense, as to which mode will be the cheaper, and there can be no doubt entertained by persons at all acquainted with the description of the work, but that it will cost much less for the whole to be done at once than at several times.

After the decided opinion I have expressed as to the propriety of contracting the river from Wincombe-lee to Hayhole, according to the lines laid down by Mr. Rennie, it is unnecessary for me now to say more than express my approval of his plan for the whole river, with the exception before mentioned. I agree with him, that it is most important that the river should be made of as equal and uniform a breadth as is consistent with its natural formation, and that all angular points jutting out into, or receding from it, ought to be remedied or removed. That where it is too narrow to allow an easy and uninterrupted flow of the tide it ought to be widened, and that, in fact, all interruptions of whatever description, to the free ingress and egress of tidal waters ought to be sedulously guarded against. This can be best done by the plans I have proposed for the part of the river between Wincombe-lee and Hay-hole, and by widening other parts of it, and having recourse to the artificial means of a powerful dredging machine.

It is unnecessary for me to trespass upon your attention by dwelling upon those particular places, where either a contraction or enlargement of the present boundaries of the river are recommended by Mr. Rennie, as he has sufficiently dwelt upon these in his very able report, in which suggestions I cordially agree ; but, it appears to me, that that part of the river which extends from Newcastle to Jarrow Slake, demands the first attention, as it is in the worst state, and of course capable of the greatest improvements.

In conclusion, I beg to observe, that I am under great obligations to your Sub-Committee, who twice accompanied me down the river, and for the important information they communicated, which I gratefully appreciate.

If you wish for a more detailed report, I shall feel a pleasure in furnishing you with it, but, as a general one, hoping this to be satisfactory to you,

I am, GENTLEMEN,

Very respectfully,

(Signed) JOSHUA RICHARDSON,
Member of the Institution of Civil Engineers.

OFFICIAL REPORT

OF THE

RIVER IMPROVEMENT SUB-COMMITTEE,

APPOINTED BY THE

CORPORATION, AND THE CHAMBER OF COMMERCE,

NEWCASTLE UPON TYNE.

Newcastle upon Tyne, June 16, 1834.

We, the undersigned Members of the River Improvement Sub-Committee, appointed by the Corporation and the Chamber of Commerce of Newcastle, having, agreeably to our instructions, surveyed the river Tyne, from Newcastle Bridge to Hay-hole, with Mr. Joshua Richardson, civil engineer, beg to submit the following observations on the present state of the river, together with such suggestions as we think best calculated to improve its navigation, gradually, and at an expense which may be commensurate with the probable funds, that may be reasonably expected to be available for this important object.

On duly considering the natural formation of that part of the river to which our attention has been directed, and the various changes, remote and recent, which have been produced by natural and adventitious causes, which are still in operation, and which have occasioned, and are perpetuating, if not progressively increasing, those impediments to the navigation which are so justly complained of, it appears obvious to us, that no partial measure can effect a general remedy, and improve the navigation of the river to that degree of which we feel satisfied it is susceptible. At the same time, we are of opinion that much good may be done by the adoption of certain remedial measures, which we shall presently notice; but we beg to premise, that, in the adoption of those measures which we have in view, we contemplate their forming a part of an ultimate and general plan for the effectual improvement of the river, to which, as far as possible, they must be rendered conducive.

It may here be necessary to notice the ultimate plan to which we have alluded.

We have carefully examined Mr. Rennie's survey of the river in 1816, and, on the whole, we think his quay-lines judiciously laid down, and not requiring any material alteration in that part of the river to which our attention has been directed.

With respect to the section or water-way of the river, we approve generally of the limits assigned to it by Mr. Rennie.

In examining the various shoals and sand-beds in our progress down the river, the causes of their formation appeared to us to be, the unequal and too great breadth of the river; together with the diminution in the velocity of the current, and the eddies produced by the tortuous direction and irregular form of its banks. The injurious effects of those causes are rendered most conspicuous by the sand banks thrown up between Wincombe-lee and Hay-hole; and by the Bill Point, the St. Anthony's Point, and the Friar's Goose Point.

The first material shoal, in passing down the river, is at Tyne Main. This nuisance may be immediately abated by dredging, and ultimately removed by building a quay from Tyne Main Staith to the Friar's Goose Quay.

The next material objects which struck our attention were the quay at Friar's Goose, and the sand-bank in front of St. Peter's Quay. The salient angle of this quay ought to be abated to the extent of twelve feet at least—it ought to be rounded with a gentle sweep, and the quay-wall continued up the shore to Tyne Main Spout. These operations would straighten the channel, and abate the sand-bank on the opposite side, by the scouring effect of both the flood and ebb tide.

The Ellison's Main shoal and the sand at St. Anthony's Point are the next important obstacles; the best mode of dealing with them is to continue the quay westward on the south side of the river, at Snowden's Hole, as nearly upon Mr. Rennie's line as may be practicable, and to employ the dredging machine. We think that it would also be of great advantage to have a quay built on the north side of the river, from Hoyle's cinder ovens to Stephenson's building-yard—to accomplish which, we advise every encouragement to be given to private individuals.

The Bill Point, with its shoals, above and below, next attracted our attention. The sharp rocky angle of the point presents a formidable obstacle to the navigation of this part of the river, not only by the sudden turn it causes, but also from the depositions of sand which are formed both above and below the point, by the eddy it causes in the flood, as well as during the ebb tide. We are so satisfied of the great injury which this projecting rock occasions to the general navigation of the river, and the obstruction which it presents to the flowing of the tide, that we earnestly recommend its abatement to the extent of fifteen feet, at least, for the present,—and by cutting it down for four feet below low-water mark. We are the more inclined to urge this measure, as we have reason to think it might be accomplished at a comparatively small expense, particularly if the rock to be removed could be converted into quay stones.

Below the point, as far as the east end of Walker Quay, the only defect of the river is, that it is too wide, thereby rendering both the flood and ebb tide too sluggish to clear it of the sand and silt which are there deposited, from time to time, as the causes which produce that effect operate. The only remedy for this is, contracting the channel to a proper size by quaying both sides of the river. But as it would require a considerable length of time to accomplish this, we recommend the quay on the south side to be first commenced, to extend from Bootland's yard to Moody's Quay, and from thence to the west end of Hebburn Quay.

From the east end of Walker Quay, and the west end of Hebburn Quay, all the way down to Hay-hole, the injurious effects resulting from the inordinate width of the river, and other causes, are still more obvious—particularly, between the Cock-crow, and Walker, Gosforth, Heaton, Wallsend, and Killingworth staiths, on the opposite side. Nothing but a commensurate diminution in the breadth of the bed of the river here can remove those extensive sand banks which impede the navigation; but as this extensive operation would require much time, and a large sum of money to complete it, we advise the partial measures of deepening the shoal parts of the low water channel, by dredging, from the high end of Hebburn Quay, running obliquely across the river to the eastward of Coxlodge spout, and thence sweeping down the north side of the river, by Walker, Gosforth, Heaton, and Wallsend spouts to Killingworth spouts; and then running obliquely across the river again, in a south east direction, by Hebburn and Springwell spouts. This, we feel persuaded, will produce considerable, and immediate benefit; and, at the same time, we recommend a quay to be built on the south side of the river, from Hebburn Quay by the Black Staith to Jarrow Quay; this quay to be built on Mr. Rennie's line. We of course consider the building of this quay to be a work of time, and to be proceeded with gradually. But we recommend the dredging of the shoal parts of the channel, as a measure for affording immediate relief.

The same partial plan which we have recommended for this portion of the river, is applicable to the remaining part of the low water channel, from Jarrow Quay, to Hay-hole; that is to say, by dredging alone, as the quaying of this part, involves the great question of quaying off Jarrow Slake, a project which does not seem to be embraced in our instructions.

The first steps to be taken, to carry these suggestions into effect, are to cut off the salient angle of Bill Point, as recommended, and to procure a powerful dredging machine,—as we are of opinion that the immediate application of an *efficient* dredging machine to the partial removal of those sands, which chiefly obstruct the low water channel, would be the readiest mode of removing the most material impediments to the navigation.

Looking forward to the ultimate completion of the general plan of improvements already alluded to, we recommend, that in all those parts of the river where quays may be required, they should, as far as is advisable, be projected upon Mr. Rennie's lines; and the more easily to accomplish this, we recommend, that the several land owners on those parts of the river should have every reasonable inducement and facility afforded for undertaking the building of such quays themselves.

There is another sand of less moment than the others, but occurring at the very outset of our passage down the river, which we have deferred noticing until the last. The sand we allude to is that which lies out from the South Shore, opposite to, and extending above, the mouth of the Ouse Burn, and also, on part of the North Shore. This sand might be almost entirely, if not wholly, removed by the elongation of the quay on Mr. Rennie's line, from the Folly Wharf, to the Ouse Burn, which would afford ample accommodation for the increasing commerce of the town.

OPINION OF THE RIVER JURY

ON THE

REMEDIAL MEASURES RECOMMENDED

BY THE

RIVER IMPROVEMENT SUB-COMMITTEE,

APPOINTED BY THE

CORPORATION AND THE CHAMBER OF COMMERCE.

September 25, 1834.

We, the jury, sworn to present all nuisances done in the port of Newcastle upon Tyne, between Sparhawk in the sea, and Hedwin Streams in the river Tyne, having been requested by Henry Bell, Esquire, Mayor of Newcastle upon Tyne, to give our opinion upon the several remedial measures recommended in a report which has been made by the River Improvement Sub-Committee, appointed by the Common Council and the Chamber of Commerce, in compliance with such request, beg leave to state that we have given such report our most attentive consideration, and have carefully perused the report of the late Mr. Rennie and examined his survey of the river Tyne, which was taken in the year 1816, and also examined Peter Knowles, William Orrick, and William Harrison, three river pilots, who were recommended to us by Mr. Thomas Smith, the master of the pilots at Newcastle, as men of great experience; and after due deliberation, we submit to the Common Council the following, as our opinion on the report of the Sub-Committee.

From the experience of many of us, and from the evidence of other persons, we are of opinion, that the channels of the river are now as good as they have been within the memory of any man living; but at the same time we must admit that the river is capable of great improvements.

With respect to the late Mr. Rennie's survey of the river in 1816, alluded to by the Sub-Committee, we think that the adoption of the *whole* of it might possibly have the effect of lessening the depth of water on Tynemouth Bar; which would more than counterbalance any benefit which might arise. And in his report Mr. Rennie appears to have entertained an apprehension that such effect might result. We, therefore, recommend the Common Council to take the opinion of an eminent engineer before they decide on its execution.

Amongst the remedial measures recommended by the Sub-Committee, that of employing *efficient* dredging machines, meets with our cordial approbation; and we cannot too strongly recommend the immediate adoption of them; being satisfied that the machine which has been applied (though a very inefficient one) has done much good.

We beg to call to the recollection of the Common Council, that as far back as the third of April last, we strongly recommended to them that they should use their utmost endeavours to induce the owners of the shore from Tyne Main Staith down to the west end of the quay at Friar's Goose, to build a quay down the whole length of that shore, for the purpose of preventing the earth and soil from falling down from the bank above into the river. As to the recommendation of the Sub-Committee, that the salient angle of Friar's Goose Quay should be removed to the extent of 12 feet, we are of opinion, that it would not be expedient to do so; as we cannot see what benefit the river could derive from its removal; on the contrary, we apprehend that it might have the effect of lessening the depth of water at Dent's Hole, which is a safe place for laden ships of great burthen to lie in.

We agree with the Sub-Committee that the river would be improved by the building of a quay at Snowdon's Hole, as near as possible on Mr. Rennie's line.

We consider that if a quay was built from Hoyle's cinder ovens down as far as Stephenson's shipbuilding yard, on the north side of the river, it would abate a great nuisance by preventing the earth, soil, and rubbish, from falling into the river from the banks there.

As to Bill Point, we agree with the Sub-Committee that the navigation of the river would be greatly improved by its removal; but instead of taking from it 15 feet, we recommend that it should be removed to the full extent of 30 feet; and that the rock to that extent should be removed down to the bed of the river, and not to the extent of only 4 feet below the low water mark.

With respect to the recommendation of the Sub-Committee, that a quay should be built from the east end of Bill Quay down to the west end of Moody's Quay, on the south side of the river, we consider it a duty which we owe to ourselves to state to the Common Council, that upon a petition which was presented to that body by Mr. William Boutland, a shipbuilder, for a licence to build a quay down that very line of shore, we gave as our opinion that the navigation of the river would not be injured by the building of such quay in the line laid down on a plan which accompanied his petition, provided the shelving rocks, which lie under water in the front of that shore in several parts, were removed, so as to allow ships to come close up to the face of the intended quay. And we beg to state, that the building a quay along the whole length of the shore in question, would, in addition to the convenience which would be thereby afforded to trade and commerce, abate a great nuisance, by preventing the earth, soil, stones, and rubbish from falling into the river from the rocky banks above the shore, and also by preventing ships from getting upon the shelving rocks before mentioned; and we consider that the facilities to trade and commerce, which such a quay will afford, and the nuisances which will be abated, will more than compensate for the quantity of tide water which will be displaced.

We now come to the recommendation of the Sub-Committee of an elongation of the public quay at Newcastle; and we beg to state that that subject has not entirely escaped the officers of the corporation; for as far back as the 17th of January last, Mr. Jonathan Cram, the quay master, recommended that this quay should be extended downwards as far as the Swerle. Mr. Cram's recommendation, as far as it goes, would certainly give a considerable extension of quay; but we think, with the Sub-Committee, that it would be much better to extend it as far down as the mouth of the Ouseburn. Whether it should be built upon the line laid down by Mr. Rennie, we will not take upon us to give an opinion; and we recommend that if such quay should be built, the corporation should consult an engineer, sufficiently experienced in river navigation, whether it ought to be built as far into the river as Mr. Rennie's quay line extends.

JONATHAN CRAM, Foreman,
LANCELOT ATKINSON,
WM. COATES,
WM. HEMSLEY,
RICHARD FARRINGTON,
WM. WHITAKER SPENCE,
JOHN BULMAN,
WM. WRIGHT,
J. BURNUP,
J. FRENCH,
M. WILKINSON,
WM. NEWTON,
HENRY WRIGHT, Jun.,
JOHN GIBSON,
WM. PEARSON,
JAMES ARCHBOLD,
JAMES B. POW,
JOSEPH CRAWHALL,
JOHN FRAM,
RALPH HOPPER.

OBSERVATIONS

ON THE

INFLUENCE OF JARROW SLAKE

ON THE

TIDES IN THE TYNE.

BY

JOHN MACGREGOR, SURGEON, ROYAL ARTILLERY.

[READ AT THE LITERARY AND PHILOSOPHICAL SOCIETY JANUARY 5, 1836.]

GENTLEMEN,

A few years ago I happened to engage in an investigation respecting the navigable state of the Tyne, which had long excited very general dissatisfaction. I did so, because I believed such an inquiry would prove acceptable—perhaps, beneficial, to the interests of the port.

I published my observations in 1832; since which time they have slept, but the appointment of new conservators having revived the hope that attention will at length be gained to this interesting subject, I again cheerfully renew my labours for the public good.

In addressing you on the present occasion, I have selected only one head of the plan of improvement for your consideration, namely, the question respecting the propriety of inclosing Jarrow Slake, and I have chosen it not only as a fit medium for resuscitating the general subject, but also because its importance renders a final decision regarding it highly necessary. Bordering upon the river, its convenient situation, large extent, and level surface, render it most eligible and desirable for every species of trade and manufactures, and for the accommodation of shipping. It seems, indeed, as if the mercantile capitalists only awaited the release of this valuable space from the dominion of antient prejudice to avail themselves of it for such purposes. Nor, in our estimate of public advantage ought we, in justice, to overlook the consideration due to the owners of the soil, who would reap a large amount of income by so wholesome an appropriation. To all these interests, the inclosure of the Slake would be clearly beneficial; our next step, therefore, is to endeavour to ascertain whether it would be so to the navigation, for, if this can be made out, its alienation from the river will, I presume, immediately follow. I am aware that even among eminent engineers of the present day, opinions are various and contradictory respecting the utility of such inlets as Jarrow Slake, some recommending to preserve these receptacles to their full extent, while others contend that they are highly detrimental. I have not met with any work or professional report in which this particular subject has been argued; I have read nothing but appeals to the ruinous consequences of one practice or the other. It appears to me that this discrepance of opinion has arisen from including in the same category the cases of estuaries, harbours on the coast, and inlets *within* rivers, which are all essentially different, and require specific modifications of treatment. Where this is not attended to, the practice may be injurious, and the principles themselves impugned, while the error is due only to their misapplication.

In treating this subject, I shall first examine the value of the several objections to the inclosure of the Slake, and afterwards briefly point out what I believe will be the real consequences of such a measure.

The first, and by far the most important objection, is founded upon a popular opinion which has obtained from time immemorial, that this slake causes more tide-water to enter the river than the sea would supply without it at such periods. This opinion has arisen, in all probability, from a misconception that the greater the space which a tide has to spread over within a river, the greater will be the velocity of the tide up the channel, and, consequently, the quantity furnished by the sea during the time of flood. Such persons speak of Jarrow Slake as *drawing in* the tide-waters, hence their common term *in-draught*, which, originating in times of ignorance, has hitherto greatly perplexed the subject by obscuring the true action of the tides in rivers, and the natural effects of dilatations in the channel.

In endeavouring to remove this misconception we must, in the first place, attend to the circumstances which promote and retard the flow of a fresh-water stream. The first are, the slope of the surface, the volume or depth, and contraction of the channel. In corroboration I quote the following principles.

1st. "An open stream derives its motion entirely from the slope of its surface, and the modifications of this motion, or its velocity, from the width and depth of the stream."*

2d. "When a stream has its section diminished by narrowing the channel, the current increases in depth, and this is always accompanied by an increase of velocity through the whole section, and most of all at the surface, and the area of the section diminishes."†

3d. "Deep waters have an energy, when in motion, not to be found in shallow running waters, by which they are enabled to continue that motion; but this is not a moving principle, it is an energy common to all great bodies."‡

4th. "The weight of water contributes greatly to its motion, so that it is not in proportion to the slope only."§

5th. "When the sections of a river vary, the quantity of water remaining the same, the mean velocities are inversely as the areas of the sections. This must happen in order to preserve the same quantity of discharge."||

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* Encyclop. Britan. vol. xviii., page 46.

† Ibid. page 47. ‡ Ibid. page 54.

§ Buffon's Nat. History, vol. i. art. 10, English edition.

|| Playfair's Outlines of Nat. Phil. vol. i., page 197.

I may here add that Zendrini, in his experiments with the pendulum, discovered that the velocities in the different parts of a section in the river Po, were nearly proportional to the square roots of the heights, when the velocities were not very great; and that it has been found, that in a parabola, of which the abscisses represent the depth of a river, and a corresponding semiordinate represents the velocity, all the other semiordinates will express velocities corresponding with the heights of their respective abscisses.*

The chief retarding causes are, friction, impact, eddies, and dilatations of the channel, or enlargement of its sections. In regard to the latter cause, we have already seen that the velocity of a stream is diminished in proportion to the enlargement of its bed; and, without authority, we learn, from common observation, that when a swollen river overflows its banks, from that moment its velocity is checked. If we kept this simple principle in view when we contemplate an upward flow, we could not fail to perceive that the same result must follow in both cases, unless we dispute the axiom that the same causes produce the same effects under similar circumstances. In short, all the conditions which modify the descending stream must, from the nature of fluids, modify in the same manner, and *ceteris paribus*, in the same degree, the upward current. It is true that there are more impediments to the latter, but this does not alter the nature and operation of those modifying influences which remain common to both.

We have now, in the second place, to inquire into the cause of the tide's ascension in a river, and whether it depends upon one or more causes. The tide in rivers, as is now well known, is merely the propagation of the great tide-wave in the ocean which has been raised chiefly by the attraction of the moon; when it comes to the mouth of a river, being confined within narrow bounds, it rises and is urged on by the force behind which brought it to our shores. When arrived at the mouth of a river it checks the current of its waters, and they accumulate there. This checks the current further up, and they accumulate there also; and this check of the stream, and consequent rising of the waters, is gradually communicated up the river to a greater or less distance. In this point of view, therefore, the tide in a river is produced solely by the force of the oceanic tide-wave. An eminent philosopher of the present day thus further describes the theory of its action. "When the tide-undulation reaches the mouth of a river, the line of the wave is observed to *revolve* round the promontory which it first reaches of the *two*, which form the opening of the river, and in this way soon meets the opposite promontory. After this, it assumes a direction at right angles to the course of the river, and advances regularly up the stream. Here, then, is a point of convergence of the tide-wave, and the magnitude of the tides will be in proportion to this convergence or swelling of the wave. The augmentation may amount to something considerable as in the case of the tides in the Wye, at Chepstow, which rise sixty feet. If we consider these very high tides of convergence as a mechanical question, they may be accounted for by what is called 'the principle of the conservation of force.' When any quantity of matter is in motion, its motion is capable of carrying every particle of the mass to the height from which it would have to acquire its velocity; but if the motion be employed in raising a smaller quantity of matter, it is capable of raising it to a height proportionally greater. In bays and channels, which narrow considerably, the quantity of water raised in the narrow part is less than in the wider, and thus the rise in such cases is greater. As the wave advances up the river, its height is gradually diminished by various causes which absorb its force. The great tide in the Wye is, in this way, extinguished before it reaches Tintern. It will be easily conceived, therefore, that a small tide would travel a shorter distance than a large one before its extinction, and that a rise of tide, which occurs in the lower part of a river, must have a certain magnitude, in order that it may affect a point in the upper part at all; and the effect on this upper point will be only that which arises from the excess of the tide at the lower point above the amount which is just perceptible above."* Now, in all that has just been stated, there is no allusion to any advenient aid to the tide within a river, its progress from beginning to end being considered due to its own inherent power. We are told that it is urged on by the power behind—that the magnitude of the tides are in proportion to the swelling of the wave at the point of convergence—that high tides are accounted for "on the principle of the conservation of force"—that as the wave advances up the river its height is gradually diminished "by various causes which absorb its force"—and that "a small tide travels a shorter distance than a large one before its extinction," thus plainly intimating that it is the external force alone which propels the tide into a river, and causes it to ascend in spite of the slope, the current of fresh water, friction, impact, dilatations, and eddies, which obstruct its progress at every step, and, finally, exhaust and destroy it. —In short, every terrene influence, however it may modify, will be found ultimately unfavourable to the progress of the tide-wave, both in the ocean and in rivers. It is true that variations of section occur in both these situations, and a consequent corresponding variation of velocity, but these are local and partial interferences, and do not, in any instance, *increase* the initial energy of the tide-wave, but, on the contrary, are found to belong to the causes which are continually weakening its power. In the sea this is verified by observing the gradual abatement of the rate of the tide as it approaches its termination. The velocity of the tide-wave in lat. 60° south, is about 670 miles an hour. It travels from the south point of Ireland to the north point of Scotland, in about eight hours. This distance is about 7°, or about 160 miles an hour along shore. On the eastern coast the velocity is less. From Buchan-ness to Sunderland, three hours gives about 60 miles an hour; from Scarborough to Cromer, also three hours about 35 miles an hour; from the North Foreland to London, in two hours, makes the speed about 30 miles an hour; from London to Richmond, in one hour and a quarter, gives us 12 miles in that part of the river. Many causes, no doubt, conspire to produce this successive abatement of rate, as shallowness, the uneven form of the bottom and shores, &c., but how many soever the obstacles may be, the great tide-wave appears to traverse the globe unaided by any power, save that which gave it origin—the attraction of the sun and moon. In the Thames, taking four distances from London Bridge upwards, we find the following rates, which are sufficiently accurate for our purpose.

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* Report on the Progress and present State of our Knowledge of Hydraulics, &c., by George Rennie, Esq., in the Report of the Fourth Meeting of the British Association, 8vo., 1835.

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* The Rev. Mr. Whewell on Cotidal Lines—Phil. Trans.

			H.	M.
From London Bridge to Putney,	distance	7⅜ miles,	0	31
Putney to Kew,	ditto	5¾ ditto,	0	17½
Kew to Richmond,	ditto	3 ditto,	0	22½
Richmond to Teddington,	ditto	2¾ ditto,	1	18¾

It is clearly seen here that the velocity of the wave diminishes as we ascend the river. Indeed the conclusion seems reasonable and inevitable, that as the magnitude and power of the tide-wave which ascends a river, depend upon the form and dimensions of the mouth, and as this power behind sustains the whole upward motion, no circumstance can add to this initial force which does not share in its formation, except meteorological causes; when this impulse subsides and departs, the whole phenomenon of a flood-tide decreases and vanishes.

Returning now to the consideration of expansion alone, if we are satisfied that this circumstance abates the velocity of a land torrent, agreeably to the axiom that, the velocities are reciprocally proportional to the amplitude of the sections, we might here pause and require our opponents to prove how expansion produces a different effect upon a downward and an upward torrent? How the height and velocity are diminished in one case and not in the other? How, in short, the law of gravity changes its nature with the direction of the stream? Meantime I shall present, upon this point, the opinion of one of the ablest engineers of the last age. It is Mr. Smeaton who thus speaks:—"The tide is spent by many turns in a river, and in filling the loops, and is thereby prevented from rising so high perpendicular as where the course is straight, and with a more regular contraction. The tide passes by before the loops are filled."* This is enough to put an end to the notion that "the loops" have any accelerating effect upon a flood tide; for if they had, they would fill themselves before the tide passed away, and behind this declaration we may defend ourselves against a host of the brotherhood.

Further, as a land-stream is not affected by an enlargement in advance until it reaches it, so neither is the tide affected by Jarrow Slake in any way whatever until it arrives there, and the waters begin to diverge in that direction. —But at the point of divergence there is a resolution of force into, as it were, two components, to which the antecedent force in Shields harbour may be considered the resultant or equivalent. Now, as each of the components must be less than the resultant, it is clear that there must be a diminution of the velocity at the point of divergence.

Again—as the rate at which the waters overspread the slake is at least three times slower than in the channel, this lesser rate cannot accelerate the greater, because it is impossible that a slow motion in advance, can accelerate a swifter motion behind. The abatement of the velocity being chiefly in proportion to the quantity of water abstracted, it is very small in a short space of time, but it is gradually accumulating from its commencement until high water, when we find that about $\frac{1}{10}$ of the whole waters of a spring tide have been withdrawn, which is as completely lost to the district above as if it had fallen into the channel of the Wear.

Again—Jarrow Slake has an ascending slope from the margin of the river to the opposite side, where it is, for the greater part, about three feet higher than the river line. As water, therefore, cannot flow against a slope, save by a force behind, it is clearly this force which sends it into the slake, which has, therefore, no power of *in-draught*, but, on the contrary, opposes the progress of the tide by this additional obstacle of slope.

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* Reports, vol. i.

Again—the diminution of velocity at the slake must, to a certain extent, re-act upon the current below, whose uniformity of speed is thus deranged; the slower motion above will have a tendency to check the velocity below which is further similarly affected by a degree of pressure from the waters on the slake. The minuteness of this united impression may render it insignificant, but the tendency is important, because some may imagine that this expansion gives relief to the stream through Shields' harbour, whereas there is no relief, nor can there be, while the slope of the channel and of the slake are contrary to the current. Nor, if there were, would it assist the current, because an abatement of quantity is, proportionally, an abatement of force.

Again—dilatations produce eddies, and every eddy destroys a portion of the moving force of a river. Though this also may appear an insignificant effect, yet with practical men it forms an important item in the aggregate of retardations.

Again—if Jarrow Slake accelerated the tide below it, then Coble Dean, the off-set at Willington Gut, and every other off-set, ought to be proportional accelerators, but this would be to raise their character to that of generators of power and efficient agents in the prolongation of the tides, which "in our philosophy," is ascribed entirely to the external force.

Variations of width in a channel can do no more than partially modify the rate of the stream as it passes their several localities, agreeably to the 1st. and 4th. axioms stated above; for to enable the sides of a river to increase, or even to preserve and prolong the initial force entire to any distance, independently of gravity, would require them to be endowed with the elasticity of animated tubes; hence we find that water will not run even on a level, and that with a slope of $\frac{1}{300000}$ it is barely perceptible on a perfectly smooth bottom

In fine, whichever way we turn in the contemplation of this question, the truth of the proposition, that "width lessens depth, and this the force and velocity," meets us, and compels assent as an intuitive perception.

Still, however, an accelerating influence is ascribed to Jarrow Slake, as a matter of fact founded upon observation. In Mr. Rennie's Report on the Tyne, made in 1813, we meet with the following remark:—"The rate of the current is generally greatest when Jarrow Slake is just covered, which is a little before half flood. Vessels entering the harbour at this time, frequently derive advantage from this great expanse; for if they enter with an adverse wind, the increase of current helps them over the bar, when otherwise they would not be able to enter the harbour at all. When the water is covering it, there is an increase of the velocity of nearly a quarter of a mile."

But this is a mere *petitio principii*, not an inductive conclusion; no relation is proved between the effect and the assumed cause, which, in a point so problematical and important to the navigation, ought to have been distinctly shown, and the dependence of the one upon the other demonstrated. We can consider it, therefore, as nothing more than an unfortunate echo of the ancient popular misconception respecting the accelerating influence of this slake, which carries improbability on the face of it, because to believe this, is to believe that a quantity of tide water, a few inches in depth, flowing over this expanse, can affect the motion of the tide in the sea for miles round the mouth of the river, and at the same time that it is flowing at a rate superior to that in the slake.

Here Mr. Rennie has evidently committed a great oversight, for, if a power of accelerating the tide, or *vis à fronte*, could be allowed to exist within the channel at all, then it ought to reside in the highest degree in the great mass of water moving in the channel with a rate superior to that over the slake. But this power is neglected, and the *vis à fronte* ascribed to the minute quantities of water successively and slowly overspreading the slake; which is to ascribe to a power whose value may be supposed 1, an effect which is denied to a similar and co-existent power whose value may be supposed 10,000; an *argumentum ad absurdum* so palpable as to suffice, with all justice to the subject, to release us instantly from any further notice of so puerile a conception.

That during spring tides there is an increase of rate at half-tide is undoubtedly true, but it is an error to suppose Jarrow Slake the cause of this, because it has long been discovered that in the sea, spring tides rise considerably higher than half the whole height in the first half of the time of flood. This impulse has also been discovered to be a property peculiar to the spring tide wave which it carries with it into all our tide-rivers. The following tables exhibit the rates at which a spring tide rises and falls throughout the whole period of a tide, both in the sea and in the Thames. At Plymouth the observed rates were as under:—

FLOOD.			EBB.		
HOURS.	HEIGHT.		HOURS.	HEIGHT.	
	ft.	*in.*		*ft.*	*in.*
1	1	6	1	1	6
2	2	6	2	2	6
3	4	0	3	4	0
4	4	0	4	4	0
5	2	6	5	2	6
6	1	6	6	1	6

At Plymouth, it is stated, the tide usually rises to 16 feet, and that this table will serve for other places where it may rise as many fathoms, or not so high, by proportional addition or subtraction. It is copied from the "Philosophical Transactions Abridged," vol. i., page 227. At page 291, of the same volume, another table is inserted, calculated for quarters of an hour, by Captain Sturmy, who mentions that his observations were made at Hoang Road, four miles from Bristol, and that this phenomenon occurs only during spring tides.

The following tables contain the result of similar observations on the gradation of the flowing and ebbing of a spring tide in the Thames, taken above and below the late London Bridge, by Mr. Francis Giles, on the 29th July, 1821, being the day of the new moon.*

Above Bridge.

FLOOD.

	ft.	*in.*
Depth when flood began,	6	0
1st hour's rise,	2	11
2d ditto,	3	0
3d ditto,	2	10
4th ditto,	2	8
45 minutes,	1	0
4 hours 45 minutes,	18	5

EBB.

	ft.	*in.*
1st hour's fall,	2	1
2d ditto,	2	7
3d ditto,	2	0
4th ditto,	1	9
5th ditto,	1	5
6th ditto,	1	2
7th ditto,	1	0
55 minutes,	0	11
Depth at low water,	5	6
7 hours and 55 minutes,	18	5

Below Bridge.

FLOOD.

	ft.	*in.*
Depth at low water,	1	3
1st hour's rise,	5	9
2d ditto,	5	4
3d ditto,	2	9
4th ditto,	2	5
48 minutes,	1	4
4 hours 48 minutes,	18	10

EBB.

	ft.	*in.*
1st hour's fall,	2	1
2d ditto,	4	4
3d ditto,	3	1
4th ditto,	2	7
5th ditto,	2	3
6th ditto,	1	9
7th ditto,	1	6
59 minutes,	0	11
Depth left,	0	4
7 hours 59 minutes,	18	10

The above observations shew the universality of this phenomenon, and that it is a peculiar property of the spring tide-wave, generated in the ocean, and carried with it into all our tide rivers. As I have not met with any explanation of its cause, it probably belongs to those inexplicable anomalies which still adhere to the theory of the tides. We have thus discovered a general and adequate cause for the increased rate of the tide at half flood in the Tyne, and to impute it to any other, more especially to that assigned in Mr. Rennie's Report, is both unreasonable and unphilosophical, and the more so when we further consider that if the flow upon the slake produced this effect, it ought to continue it during the subsequent period of the flood; but we have just seen that the reverse takes place. Again—if the slake were the cause of this phenomenon, it ought to occur in neap tides, when the slake is also covered to some depth, but Captain Sturmy has informed us that it is confined to spring tides.

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* Mr. George Rennie's Report, cited above.—also the *Edinb. New Phil. Journal*, Art. 5, 1826-7.

Thus we get entirely rid of the assertion, that Jarrow Slake possesses a power of *in-draught*, as a fact founded upon observation, which, if it could have been sustained, would have triumphantly refuted all reasoning to the contrary.

So far then, as we have yet pursued the subject, it appears that this expanse does not increase the velocity, but decreases it by invading the mechanical principle of the conservation of force.

But this is not all, for it likewise diminishes the momentum or moving force of a tide, so necessary to enable it to contend against the current of fresh water, the slope, and other impediments to its progress.

In the beginning of this paper, it was noticed as a principle, that "the weight of water contributes greatly to its motion," a principle which applies equally in all cases. It is indeed the chief element of the motion of water, and is eminently necessary to the existence and prolongation of a flood tide.

The momentum, or quantity of force in a moving body, is compounded of the velocity and the mass or weight of the body, and is as the squares of these quantities singly, if either be doubled the momentum will be quadrupled, but if both be doubled, it will be raised to the 16th power. On this point, Mr. Smeaton observes, "the force of water in scouring away a sand bank, or deepening a channel, is always proportionate to the quantity acting in a given time, and the vigour or force with which every equal part of the quantity does act. Thus, for instance, if a ton of water was to pass over a sand in a minute's time, and every gallon of that water exercised a force on that sand, which may be represented by unity, then the whole force exercised in a minute's time on that sand may be expressed by the number 250. But if the quantity acting in the same time be doubled, and the force with which every gallon acts be doubled also, as it will if the velocity of the current be doubled, then the force in a minute's time will be four-fold what it was before." Here, however, Mr. Smeaton makes the new power too small, for, since it is as the square both of the velocity and quantity, the expression becomes $2+2\times4=16$.

It might be difficult to assign the value of the decrement of momentum corresponding to the infinitesimal decrements of velocity and weight, but as that of the latter becomes gradually more tangible, we soon acquire, in respect of it, a ratio which will enable us to perceive the effect distinctly enough for our purpose.

Mr. Rennie states, that during a spring tide, on the 31st of May, 1813, 726,621,000 cubic feet of water entered the river. This is about 20,760,600 tons. Now, as the area of the slake is 338 acres, and as I found from rude measurements, the average depth of an average spring tide to be five feet, we find that the slake abstracts about 2,000,000 of tons during the two hours and a half in which a spring tide is filling it. If we then suppose the tide to rise equally during this time, we shall find that above 400,000 tons are abstracted from the channel every half hour, the square of which will give the proportional loss of momentum which the tide experiences every half hour, above this locality, in consequence of the loss of this quantity of water only.

The efficacy of momentum in augmenting the height of a tide by ponding back the fresh water is considerable. When not affected by the tide the surface of the water slopes, but when the tide begins it raises the surface of the lower part of the river, so as to diminish the slope of that part; that this altered surface extends successively higher and higher up the river, and is nearly horizontal at high water; after that, the tide surface again descends, and the effects of it disappear in succession from the parts of the river, beginning with the upper parts, till the low water surface is again attained. Now, the degree of depth produced by this means, depends greatly upon the volume of the tide opposed to the fresh water, hence, there may be a tide in a river without any up-current at all, and a powerful impulse will prolong a tide far beyond the limit to which the sea-water extends.

But the diffusion of two millions of tons of water in the upper part of the channel, must, from its bulk alone, increase the height of tide there. I am aware, that in the case of a descending stream, the addition of a much larger quantity would produce only an increase of velocity, owing to the operation of gravity; for, according to professor Playfair, a river whose breadth is 10 feet, and depth 1, requires the addition of another of equal dimensions to raise the height to 1·4332, and the original velocity from 37 to 50, nearly.*

The experiments of Genneté, made at Leyden, in 1755, give a different result, and are much less favourable to the increase of the height by even more considerable augmentations of volume.† But in the case of an upward flood acting against gravity, and constantly resisted by the fresh-water, we find that the ratio of the height increases while that of the velocity decreases until high water, when the one attains its maximum and the other its minimum.

The loss, then, of the assistance of 400,000 tons of water every half hour, in producing depth, by ponding, and by adding thus much to the general mass above, cannot fail to be viewed as an important deterioration of the navigable state of the river.

This quantity would fill a branch from the river two miles long, and a quarter of a mile broad, to the depth of five feet; and, if the slake were ten feet deeper, it would abstract a quantity that would fill a branch six miles long and of equal breadth, to the same depth, which would probably diminish the height of a spring-tide, at Newcastle, more than one-third.

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* Outlines of Nat. Philos., vol. i. page 196.

† Mr. George Rennie's Report, as above.

We have a notable example before us of the injury which the navigation sustains by the division of a stream. The river Derwent, which passes Derby, was made navigable in the beginning of the last century; but since the formation of branch canals to the Erewash and Trent, the navigation of the river has ceased. These branches are each eight and a half miles long, but the amount of water which they withdraw, I am unable, at present, to state. But, it seems evident, that if they were shut up, and the old channel cleansed, the navigation would be restored. So, if Jarrow-slake withdrew six millions of tons from the Tyne, and thereby diminished spring-tides one-third at Newcastle, would the former depth there be recovered by inclosing it. If, therefore, it would be beneficial to shut out a great expanse, it must, upon the same principle, be proportionally advantageous to shut out a small expanse, and thus preserve the velocity, momentum, and depth, to their full extent. As we have shown that the slake does not increase the velocity of a tide between it and the sea, and as we know that only a certain amount of water enters the river during a certain time, it is clear that if any portion of this be diverted from the channel at the slake, less will remain to pass upwards.

But Jarrow Slake is further injurious to the river by diminishing the scouring power of the ebb tides, which is manifestly too feeble at present.

On this point Mr. Smeaton observes—“ The removal of a sand-bank must be effected by the ebbs and back-waters, which should be conveyed as entirely, unitedly, and directly to it as possible, so that they may exert their whole undiminished force and power thereon, without meeting with any stops or impediments in their way. For the force of water in scouring away a sand-bank or deepening a channel, is always proportionate to the quantity acting in a given time, and the vigour or force with which every equal quantity does act.” To the same purpose Guglielmini observes, “ The waters of the sea, which, during a flood, enter into the beds of rivers, returning back with the ebb, help to clear out the bed, and to sweep away the deposits."

Thus it appears that Jarrow Slake decreases both the velocity and momentum in the contiguous portion of the channel, and the depth, and scouring power of the ebb tides in the parts above; all which consequences result from the infringment of the principle of *the conservation of force*. It is for the same reason that I have elsewhere recommended the exclusion of Coble Dean from the river and the contraction of the Long-reach.

We now come to a brief consideration of another objection to the inclosure of the slake, namely, that during a great *fresh*, it takes in so much water as reduces the height of an inundation in Shields' harbour, and thus eases the current there in such seasons. The great flood of 1771, rose at Newcastle, 7 feet 4 inches above the height of a spring tide. "The utility," says Brand, "of Jarrow Slake, appeared in this disaster, as it took in so immense a body of water, that at Shields the flood was no higher than a spring tide."

Here we may remark an easy and natural acquiescence in the proper effect of expansion in regard to a downward stream, while, as stated in the outset of this paper, the same consequence was denied to result from the same cause, in the case of an upward current, at least by popular opinion. If a knowledge of the laws which govern the motion of streams be necessary to discover this unity of effect, then we can readily excuse those who had not the means to make a discovery to which analogy alone seems sufficient, the parallelism being self-evident.

It is undoubtedly true, that while the slake is filling from a land-flood, both the velocity and the quantity which would otherwise pass to the sea with the main stream, will be somewhat abated, just as happens in the case of a spring-tide, but infinitely less in degree, and by no means to the extent represented by Mr. Brand, which is the error upon which we at present animadvert. To show this in a plain manner, we have only to consider, that the slake, being a *cul de sac*, can receive but a limited quantity of the land-flood, and no more than is sufficient to fill it to the height of the waters in the channel, which, if they surpass a little the height of a spring-tide, may send into the slake somewhat more than two millions of tons. Now, taking the width of the channel here at one-third of a mile in such seasons, the average depth at 15 feet, and the rate at seven miles an hour, as in the flood of 1831, we shall find that about 27,878,396 tons pass by this slake in an hour; and if the flood should continue at its acmé for twelve hours, there will, in this space of time, escape into the sea 334,540,752 tons, while Jarrow Slake has abstracted, at most, 2½ million tons. I do not profess to have given exact calculations of the relative quantities, this being unnecessary where their difference is so immense, and where the tendency one way or other is all that is sought. But rude as those approximations are, they will, I hope, be sufficient to convince us of the utter insignificance of this slake to the safety of Shields at such seasons.

That land-floods have their height reduced as they approach near to the sea, is a fact which has long been known; but it is likewise an error to assign Jarrow Slake as the cause of this, as may be inferred from what has just been stated. But it was the philosophical acumen of Major Rennel which revealed the cause and removed all doubt respecting it. In his "Geography of Herodotus," he informs us, that, "all such inlets situated near the borders of the ocean, cannot, during the time of a land-flood, be it ever so great, receive more than they do during a spring-tide, nor so much, if it coincides with the period of a neap, because the ocean influences the level of all waters that communicate with it, except such as cataracts." In speaking of the Nile, in the same work, he further explains this phenomenon. "For, although the river," he says, "may swell thirty or more feet, with the periodical season, in parts removed from the sea, yet, at the point of its junction with the sea, it cannot rise at all, since water cannot be retained in a heap, but must form a common level with the mass with which it mixes. The land-flood, therefore, will form a slope of such a nature, as its gravity combined with the declivity of the stream will admit."

This fully explains the cause why the flood in the Tyne, of 1771, rose no higher than a spring-tide, in Shields' harbour. It shows also, that the ocean is the sole controller of the height of land-floods near the mouths of rivers, and that the agency of Jarrow Slake in producing this effect in the Tyne, is as imaginary as that of its accelerating a tide from the sea.

There remains but one other objection to dispose of, which is, that the slake serves as a reservoir of tide water by which the ebb is prolonged, and a convenience thereby afforded to the shipping in Shields' harbour. But this, at first sight, is impossible, because its waters move off as they come on, in conjunction with those of the main stream, and the slake is empty before half ebb; and, because the gradual addition of its waters to the ebb current, must accelerate rather than retard its motion. No partial inclosure could form it into a reservoir for subsequent use or in any way improve its power, and I presume no one would venture to propose the expensive construction of a wall with flood-gates, in the hope of thus scouring Shields' harbour, which it would not do generally nor usefully, experience having shown that the effect of a large dam when its waters are let loose, is to tear up the bed of a river, ploughing it into deep furrows with ridges of sand and earth on each side. Commotion, and great derangement of the bottom of the harbour, would be the only consequences of such a measure, which must necessarily impair, perphaps destroy the navigation. As to the shipping, such a back-water would be of little use to them, since it would not add an inch to the depth on the bar, because it could not raise the level of the sea. Large vessels, therefore, would be still obliged to remain in the harbour until the tide did this for them. It would be useless to pursue this chimæra farther.

In conclusion, we have to remark, that the inclosure of the slake could not possibly prevent the whole waters of a tide from ascending beyond it. In the first place, the friction along the side of the inclosing wall or quay, would be less than upon the bottom of the slake by more than one-half. In the second place, as the whole amount of a tide would then, as now, be propelled into Shields' harbour, the almost infinitesimal portions which are now successively deflected into the slake at every moment of the rise, must, from the cohesion of water, adhere to the great mass in the channel, and thus be borne along with it and accumulated above, instead of in the slake. This must happen, because they form integral portions of a moving mass of water, all the parts of which must move together in the same direction in a free channel.

This salutary consequence appears to be the only one which can possibly result from the inclosure of the slake. Throughout I have felt the importance of this great and long agitated question, and have, accordingly, given it my best attention; but in all the aspects in which the subject has presented itself to my mind, I have not found a single sound argument in defence of the alleged propriety of keeping open this slake; but, on the contrary, many substantial reasons why it should be inclosed; above all, the improvement of the navigation.

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